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TOPIC 3 - RIVER BASINS, RESERVOIR SEDIMENTATION AND WATER RESOURCES

Session 3.6 - Groundwater modelling

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Session Description Groundwater resources are the most important source of water for manifold purposes besides being an important factor for a lot of engineering geological problems. Groundwater needs of being protected and carefully managed also in a scenario of climate change that can severely affect groundwater supply. Therefore, the analysis and the modelling of the processes related to groundwater management are paramount problems for engineering geological study. The difficulties in modeling groundwater systems are related to their intrinsic complexity and to the potential high not linearity of their behavior in response to external input. Aim of the session is to bring together the experiences in analysis and modelling of groundwater systems, with different approaches and in different hydrogeological environment. It will be the place for Engineering geologists to share different experiences on this issue. Therefore, we encourage and welcome the submission of contributions, about any aspect of groundwater modelling analysing their behaviour, field experiences, modelling approaches, case-studies etc..

Distribution, discharge, geological and physical-chemical features of springs in the Turin Province (Piedmont, NW Italy)

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A statistic analysis of 1571 exploited springs of the Turin Province is reported in a database, taking into account the exploitation concessions from the *Water Resource Management Service* archives and other documents. The springs were mapped with a GIS on a new specifically drawn geolithological map of the province.

The Turin Province shows different landscapes, the high reliefs of the internal Alps (until 3676 m), the morainic amphitheatres and Tertiary Piedmont Basin hills and the alluvial Po Plain (more than 140 m). The exploited springs are relatively well-distributed in the different altitude ranges. Two peaks of spring number occur at 800-1100 m in the lower mountainsides near inhabited areas (426 springs = 26.5%) and at 140-300 m in the fluvial plains (245 springs = 15.3%). A minimum number of springs occurs instead at 300-400 m in the hill sectors and highest terraces (only 41 springs). The number of springs gradually decreases upward between 1100 and 2500 m.

The average density of the springs of the province (6824 km^2) is 0.23 spring/km^2, i.e. one spring every 4 km^2. The density rises to 0.31 spring/km^2 in the mountain basins and their morainic amphitheatres (1408 springs over 4426 km^2), i.e. one spring every nearly 3 km^2. Only the Malone Valley density (one spring every 1 km^2) diverges from this value. The spring density in the plain and hill sectors is remarkably lower: one spring every 10 km^2 in the southern Po Plain, one every 15 km^2 in the northern Po Plain, one every 19 km^2 in the Turin Hill (boxes 9, 12, 13 in Fig. 1) and one every 53 km^2 in the Poirino Plateau (6 in Fig. 1). The Dora Riparia Valley is the area with the highest number of springs (406 = 25.8%) followed by the Chisone (214 = 13.6%) and the Stura di Lanzo valleys (162 = 10.3%).

The springs was catalogued also by use. The most of springs (1023 = 65%) are used for drinking water supply; the water from 369 springs (24%) is used for irrigation and from 92 springs (6%) for sanitary use. The remaining springs (3%) are used for industrial purpose (15 springs, e.g. for dairy), pisciculture (17) and waterpower (11). Some springs (8) are used no longer and finally 36 springs (2%) results of unknown use. The most of the mountain (15 to 20 in Fig. 1) and amphitheatre (5 in Fig. 1) springs (72%) is for drinking use. An irrigation use instead prevails (86%) in the plain (1, 2, 3 in Fig. 1) and in the Tertiary Piedmont Basin springs (6 to 14 in Fig. 1), where the drinking water is derived from wells.

Among the 1207 springs of well-known discharge, more than half (54.7%) has discharge lower or equal to 1 l/sec (661 springs, of which 144 with discharge of 1 l/sec), followed by the discharge class between 1-3 l/sec (349 springs). Only 43 springs, including 8 drainage trenches, have a declared discharge higher than 10 l/sec. The Pian della Mussa draining trench (Stura di Lanzo Valley) has the highest discharge (average maximum 500 l/s and a peak of 720 l/sec measured on 2008 May 25 during a prolonged rain event).

An overall discharge of 4149 l/s is obtained by summing the maximum discharge of the 1207 springs, which correspond to a middle value of 3.44 l/s. Taking in account only the 47 springs with well-known maximum and middle discharge, the total middle discharge results 0.61 of the maximum discharge. Using the same ratio for the 1023 springs exploited for drinking use, we get a total middle discharge of 2158 l/s. The daily supply of water is therefore 186451 m^3, corresponding to 81 l of water for each of the 2.3 million inhabitants.

The springs are generally linked to an extended Quaternary cover and/or to the fractured bedrock, with suitable morphological conditions.

In the mountain basins 1279 springs were listed, corresponding to the 81.4% of the total number of springs. The aquifers of the most alpine springs are constituted by Quaternary cover (gravitative, colluvial, glacial and alluvial), while the metamorphic bedrock forms their basal aquiclude. The bedrock lithology is anyway important, because the Quaternary cover derives from the erosion of the bedrock that controls the spring chemistry. In detail over a third (566 springs = 36%) lies on the gneiss, micaschist and quartzite (Sesia-Lanzo Zone, Dora-Maira and Ambin units, 18, 19, 20 in Fig. 1). Their great number is linked not only to the widening of these lithofacies (about 1050 km^2, corresponding to the 15% of the province area), but also to their distribution closely to the very inhabited alpine piedmont. Many springs are hosted in the Piedmont Zone calcschist (16 in Fig. 1) (297), widespread in the upper Dora Riparia and Chisone valleys, and in the serpentinite and metabasite (18 in Fig. 1) (229), prevailing between the lower Dora Riparia Valley and the Lanzo valleys. Numerous springs (147) lie also into Gran Paradiso and Dora Maira Penninic ortogneiss (20 in Fig. 1). On the whole, springs linked to these four groups of rocks units correspond to the 79% of the total springs of the province and yield the 82% of the exploited spring water.

The Tertiary Piedmont Basin made of sedimentary rocks (6 to 14 in Fig. 1), outcropping at the south-eastern boundary of the province (5% of the total area), hosts only 27 springs (1.7%), almost all used for irrigation. Finally 265 springs (16.9%) occur into the fluvial plains and the morainic amphitheatres consisting of Quaternary deposits. Most springs flows from the Holocene fluvial cover (111) (1 in Fig. 1) and from the late Middle Pleistocene fluvial and fluvioglacial deposits (71) (2, 3, 4 in Fig. 1). Over two thirds of them are used for irrigation.

As regards the springs hydrogeological features in the Turin Province, small discharge springs (lower than 1 l/s or few l/s at most) are linked to thin and discontinuous quaternary deposits resting on the mountainsides. Springs with discharge higher than a few l/s up to a few dozen of l/s, are linked to significant size aquifers, corresponding to large and thick landslide bodies or, more frequently, to deep-seated gravitational slope deformations (DSGSDs). More remarkable springs, of dozen of l/sec of magnitude, need of more wider aquifer that are only possible into a very fractured bedrock as in the DSGSDs, but in presence of morphological features suitable to carry all the waters towards one outlet, as the Montellina spring in the

Dora Baltea Valley. Otherwise an unusual high discharge spring is caused by a single open fracture drawing all the water from an adjoining torrential incision.

At last, the most of the installations of water drawing higher than 30 l/sec aren't natural springs, but they correspond to very long drainage trenches (Pian della Mussa, in the Lanzo Valley; Vistrorio, in the Chiusella Valley) or galleries (Sangano, Trana and Villarbasse in the Sangone alluvial fan).

Several sources (28) have been analyzed relatively to the main physical-chemical parameters. The electric conductivity shows an average value of 190 μS/cm, and ranges from less than 100 μS/cm, in zones where silicate rocks outcrop (Chisone and Lanzo valleys), to more than 400 μS/cm, especially in Dora Riparia Valley, where carbonate and evaporite rocks occur. The bicarbonate, with an average value of 100 mg/l (range between 5 mg/l and 260 mg/l), is the ionic species which governs the electrolytic conductivity of the spring waters. The sulfates (mean value of 15 mg/l, variable between 2.5 mg/l and 110 mg/l) constitute the secondary anionic species, because of the sporadic presence of gypsum evaporite, while the chlorides (average content of 0.95 mg/l with a variation range between 0.16 mg/l and 5.98 mg/l) do not influence the water conductivity in a perceptible way. Nitrates concentration generally remains below 5 mg/l. The Total Hardness exceeds 25 French Degrees only in Dora Riparia Valley. The sampled waters have bicarbonate to sulfate alkaline-earth facies and, limited to the analyzed parameters, they satisfy the law limits on drinking water.

Fig. 1. Springs distribution (number and total maximum discharges in l/s) in the different geolithogical units of the Turin Province, consisting of the metamorphic bedrock (units 20÷15), Tertiary sedimentary rocks (units 14÷7) and Quaternary sediments (units 6÷1). The percentages are referred to the total number of springs.